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FEP FACULDADE DE ECONOMIA UNIVERSIDADE DO PORTO

Towards Circular Supply Chains in the Plastic and Packaging Industry

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Dissertation

Master Program in Economics and Management of Innovation

Guided by

Ricardo Augusto Zimmermann

2023

Resumo

Nas últimas décadas, a sustentabilidade tem sido cada vez mais destacada como um fator fundamental, em todos os aspetos da sociedade e a Economia Circular ganhou visibilidade como uma melhor alternativa aos atuais modelos de consumo linear, que contribuem para a escassez de recursos naturais e acarretam muitas incertezas. A transição para este novo paradigma implica uma visão holística de toda a cadeia de valor, minimizando a utilização de matérias-primas (ou virgens) e aumentando a quantidade de material que é reutilizado ou reciclado e é introduzido novamente no sistema, oferecendo uma nova e apelativa perspetiva ao conceito de sustentabilidade da cadeia de abastecimento. Embalagem é o maior mercado da indústria do plástico, e embalagens de plástico representam 26% do consumo global de embalagens, o que torna o impacto ambientam ainda mais preocupante. Este estudo teve como objetivo identificar e analisar as práticas, os impulsionadores e as barreiras ao desenvolvimento das cadeias de abastecimento circulares na indústria de plásticos e embalagens. A análise de um estudo de caso único, incorporado e transfronteiriço, revelou os esforços realizados nesta indústria, bem como as suas dificuldades, preocupações e impactos percecionados na cadeia de valor. Adicionalmente, os resultados demonstraram o impacto das novas tecnologias como impulsionadoras de inovação e como uma ferramenta importante para criar valor ao longo da cadeia de abastecimento. Finalmente, este estudo revela como a comunicação é fundamental nesta indústria para ultrapassar ideias pré-concebidas, reforçar a confiança ao longo da cadeia de abastecimento, cumprir a legislação, melhorar os processos e contribuir para a preservação do planeta, mantendo-se economicamente rentável.

Palavras-Chave: sustentabilidade, cadeia de abastecimento, economia circular, tecnologias.

Abstract

In the last few decades, sustainability has been increasingly highlighted as a fundamental factor in all aspects of society and Circular Economy has gained visibility as a better alternative to the current linear-consumption models, which contribute to the scarcity of natural resources and carry many uncertainties. The transition to this new paradigm implies a holistic view of the entire value chain, minimizing the use of raw (or virgin) materials and increasing the amount of material that is reused or recycled back into the system, offering a new and compelling perspective on the supply chain sustainability domain. Packaging is the largest plastic industry market, and plastic packaging represents 26% of global packaging consumption, making the environmental impact even a bigger concern. This study aimed to identify and analyze practices, drivers, and barriers to the development of circular supply chains in the plastic and packaging industry. The analysis of a single-case embedded, cross-border study, revealed the efforts made in this industry as well as their difficulties, concerns, and perceived impacts on the value chain. Additionally, the results demonstrate the impact of new technologies as a driver of innovation and as an important tool to create value along the supply chain. Finally, this study reveals how communication is fundamental in this industry to overcome misconceptions, strengthen trust along the supply chain, comply with legislation, improve processes, and contribute to preserving the planet while remaining economically profitable.

Key Words: sustainability, supply chain, circular economy, technologies

Summary

Table Index

Abbreviations

AI – Artificial Intelligence

CE – Circular Economy

EPR - Extended Producer Responsibility

IoT – Internet of Things

PPI – Plastic and Packaging Industry

PCR – Post-Consumer Recycled

SC – Supply Chain

CSC – Circular Supply Chain

1. Introduction

Sustainability-related issues have increasingly attracted the attention of researchers, policymakers, managers, and other stakeholders (Farooque et al., 2019). Adopting sustainable practices is a way for companies to go beyond economic concerns and demonstrate the commitment and importance given to social and environmental responsibilities (Holder-Webb et al., 2009).

Circular Economy (CE) has emerged as an alternative to the current linear production and consumption model (produce – use – dispose) (Geissdoerfer et al., 2017). Although the development of Circular Supply Chains (CSC) still carries many uncertainties regarding its application, the need for a more sustainable sociotechnical system, where people and technologies work in collaboration is clear (Emery, 1993; Fischer & Pascucci, 2017; Saroha et al., 2022) as well as the urgency of a transition towards CSC.

This study adopts a model that considers the existence of ten strategies that can be applied across supply chains (SC) to guide companies to minimize the use of virgin raw materials and to increase the percentage of materials returned into the system, delivering a new and gripping perspective to the SC value (Awan et al., 2022; Farooque et al., 2019; Geissdoerfer et al., 2017; King & Locock, 2022; Potting et al., 2017; Saroha et al., 2022). The transition to a CSC model requires a holistic approach, improving the actual mechanisms as well as developing new ones.

Although the discussion about sustainability covers all the possible sectors and processes along SCs, plastic has often been seen as the "bad guy", whose importance is underestimated and raises major concerns due to its environmental impact and CO2 emissions (Johansen et al., 2022). Despite the exacerbation of prices of energy and logistics as a consequence of recent events, such as the war in Ukraine and the COVID pandemic, only in 2021, more than 390 million tons of plastic were produced worldwide – 57,2 million tons in Europe. These numbers made plastic one of the most used materials (PlasticsEurope, 2022). Packaging appears as the largest market in the plastic industry, representing 26% of global consumption (King & Locock, 2022; PlasticsEurope, 2022). Thus, considering: (1) the uncertainties about the creation of CSCs; (2) that most of the research carried out in previous studies present only a theoretical perspective; and (3) that the practical results of the adoption of CSC, especially in the Plastics and Packaging Industry (PPI), are unclear; this work intends to study the actions engaged by companies to promote the development of CSCs in this sector. The following research question will be addressed:

RQ: How do circular supply chain practices can be applied in the plastic and packaging industry and contribute to increase environmental sustainability?

Considering its environmental impact, stopping making and using plastic could be defended as a beneficial option for society. However, plastic is one of the most used materials worldwide, and has a set of characteristics, such as being versatile, accessible, resistant to weather and time, which make it a ground-breaking innovation for human progress (Dow, 2021; PlasticsEurope, 2022). Thus, a more responsible use of this material is needed. In this sense, the main goal of this study is to identify and analyze best CSC practices that can be applied in the PPI. A case study of a big player in this sector is presented to understand their efforts and motivations towards the development of a CSC model, as well as their difficulties, concerns, and perceived impacts about how they affect and influence the entire value chain.

This dissertation is organized as follows: the following chapter presents a literature review on the necessary key concepts for the study, such as Circular Supply Chains, the R Strategies, barriers and challenges for circular economy, and the role of technologies. The third chapter refers to the method of analysis used and how the data were collected. The fourth chapter presents the data collected in the study, followed by the last chapter with the conclusions, as well as limitations of the study and directions for future research.

2. Literature Review

In this section, we analyze the literature on concepts and strategies towards a CSC that have been suggested and implemented, as well as its barriers and challenges, and the role of digital technologies as a facilitator of the development of CSC.

2.1. Circular Supply Chains

Sustainability does not have a unitary definition. Robinson (2004), defends that it can be understood differently from person to person, and can be influenced by political and philosophical stands. In this study, sustainability is assumed as the development that assures the present needs without harming the planet's resources or compromising the needs of future generations (Elkington, 1994).

Walter Stahel is often recognized as a pioneer in the idea that changing the business model to a self-replenishing economy allows the equilibrium between the environment and economy; making it possible to produce quality and profitable products, while minimizing waste or leaking energy, through the development of closed-loop ecosystems (Awan et al., 2022; Brennan et al., 2015; Geissdoerfer et al., 2017). A closed-loop is a model of the production systems and reverse logistics, in which materials, components, and products are designed through a unique system to continuously add, recreate, and preserve value during the entire life cycle of the product (de Giovanni, 2022; de Lima et al., 2021).

However, in the transition from a linear to a CE, one of the main challenges is to overcome the uncertainties about how the inter-firm relationship can be aligned, introducing new entities and material to the processes while keeping the status quo of a linear economy (Fischer & Pascucci, 2017).

2.2. The R Strategies of Circular Supply Chains and the Plastics Life Cycle

CSC implementation has been based on the adoption of R strategies, whose number and sequence have evolved in the last decades (de Lima et al., 2021). Potting et al. (2017) propose a model that includes ten strategies: Refuse, Rethink, Reduce, Reuse, Repair, Refurbish, Remanufacture, Repurpose, Recycle, and Recover.

Refuse strategy refers both to the consumer and the producer. The consumer side requires a critical position and conscience of the purchasing process and decides what is needed or can be less used (for example., unnecessary packaging or shopping bags) (Reike et al., 2018).

The producer side refers to the prevention, such as decisions to avoid hazardous and virgin materials during production (King & Locock, 2022; Reike et al., 2018). Moreover, companies must be aware of consumer behavior trends in refusing certain products or materials and consider them in the design and production processes.

The rethink strategy is related to the design of products keeping or improving their quality, ensuring that all the components are recycled and can be continuously reused in a closed-loop, ensuring that the carbon footprint is minimized, and the resources are not wasted (Awan et al., 2022; Fischer & Pascucci, 2017); it is also related to the consumer behavior of rethinking the need or the willingness to consume certain products or materials. On the PPI, the decisions to use less plastic or find the best ratio of recycled and virgin plastic and the type of polymers to use is a challenge due to the high-quality standards for the industry (for example, the concerns for migration of toxins, additives, or mixed polymers that may affect the quality, durability, or even the value of the products) (Johansen et al., 2022).

The reduce strategy is about reducing the product's packaging and consumption and transport levels, as well as on the producer side, reducing the waste on production and shipping levels (PlasticsEurope, 2022).

Reuse is a strategy that implies the use of one product by another consumer for the same purpose, without any adaptation or repair (Reike et al., 2018). From a product perspective, consumers are reluctant to purchase used or old products for lack of trust in their quality. However, the desire to possess high-end products (usually more expensive) can help raise circularity via pooling and sharing products (e.g., online platforms such as eBay, OLX, and other marketplaces) (Reike et al., 2018). The initiatives at the organization level with sharing policies within the company or other companies will increase the circularity (Awan et al., 2022). From a packaging perspective, if producers focus on services and not only on products, infrastructure for a reverse-logistic network can be developed when the package, if not disposable, can be returned after use and reused (Network for Circular Plastic Packaging, 2020). For example, OriginalRepack.com offers packaging solutions with a unique barcode that rewards the consumer when the package is returned; while P&G and Unilever provide some free pick-up points where the consumer can leave the pack after receiving its order (de Lima et al., 2021; Khan, 2022).

The purpose of the repair strategy is to extend the lifetime of the products (Awan et al., 2022; de Lima et al., 2021). Being aware that many consumers do not trust the quality of

repaired products, the European Commission has been working on a revision of consumer law to assure that the consumer has access to clear information about the products, such as lifecycle and repair services, and establish new consumer rights regarding the availability of spare parts and repair services (European Commission, 2020).

The refurbish strategy refers to the process where many components of a product are replaced or repaired, keeping its structure and functionality with new components to perform as well as new (Reike et al., 2018). There are some struggles to implement this strategy due to a lack of skilled people to perform the service. However, partnerships with customers or other firms are being pointed out as an opportunity (de Lima et al., 2021).

Remanufacture is gaining momentum as an important strategy for a closed-loop SC as a hybrid system that can revolutionize the system and create economic impact (de Lima et al., 2021). A remanufacture product means disassembling, checking, and replacing or repairing components for new ones (de Lima et al., 2021; Reike et al., 2018). As an example, the company Thousand Fell established a partnership with TerraCycle and UPS where customers can return old pairs of shoes to the manufacturer getting a voucher to buy new ones (Fleming, 2022). And when a product reaches the end of its lifecycle, its components can be reused on a different product than the initial, being part of its purpose strategy. The Australian company Close de Loop has discovered a way to transform old printers' cartridges and soft plastics into roads. Combined with other components, such as asphalt, they create a product that lasts up to 65% longer than traditional asphalt (Thornton, 2019).

Recycle is undoubtedly the most disseminated and cited strategy in the literature, even though it is frequently misguided with other concepts to avoid using new mining materials or resources or point a solution for a shorter route to a closed loop (Reike et al., 2018). When a product reaches the end-of-life phase, it moves to the collection, and ideally, the products are separated by the citizens, collected by waste pickers, and sorted through a recycling system (King & Locock, 2022; PlasticsEurope, 2022), resulting in raw materials to new products, which will lead progressively to a reduction of the need for virgin raw materials. In some counties, it was created a program to promote the proper separation and collection of bottles where the consumer pays for a deposit tax when a bottle is bought, and this cost is refunded when the bottle is return to be recycled or reused (Yvonne, 2022). Digital technologies will also positively impact the quality of the process with adequate mechanisms (de Lima et al., 2021).

Finally, recovery is not a widely considered strategy and, according to Potting et al., (2017), it should have the lowest priority and only be applied to products that cannot be reintroduced as raw material in the SC after the recycling phase, but can be used for energy recovery (such as the use of methane for power generation or gasification that helps decomposed organic materials; technologies that create syngas, a clean alternative to fossil fuels to generating electricity or synthetic diesel (Ragaert et al., 2017); produce hydrogen) (Aiello & Morante, 2022)) which is a better alternative than landfills.

2.3. Barriers and Challenges of Circular Supply Chain

There is a clear understanding that CE is a sustainable way for companies to produce while avoiding raw materials scarcity and reducing environmental footprint of products. However, most strategies have not been properly tested yet and therefore there are many uncertainties about their results since the decision-makers cannot estimate an outcome or occurrence, that could lead to a positive or a negative result. The ambiguity surrounding the legislation hold back industry actions and investments, as long as stakeholders do not reach an agreement that leads other actors to act responsibly, and costs are always a key factor. Society is becoming more aware of the environmental problems, shifting customer demands, and pressing SCs and the government to take more sustainable decisions. However, the questions that still arise are several, as presented in Table 1.

Table 1 - Barriers and Challenges of Circular Supply Chain

Barrier	Description	References	Rs impacted
Uncertainties	Resistance to change and afraid of the risk since the result cannot be estimated if it will have a positive or negative impact. Also, it is often not possible to predict the quantity and quality of "end-of-life" products or parts to be used as input for R strategies	(de Lima et al., 2021); (Simangunsong et al., 2012)	Refuse, Rethink, Reduce, Reuse, Repair, Refurbish, Remanufacture, Repurpose, Recycle, Recover
Agreements along the Supply Chain	The methods and mechanisms adopted along all the phases of the circle must be credible and accepted throughout and by the entire SC.	(de Lima et al., 2021) (European Commission, 2020)	Rethink, Reduce, Reuse, Repair, Refurbish, Remanufacture, Repurpose, Recycle
Privacy and Protection	Afraid to risk privacy and security data, especially for companies that have protected innovation.	(de Lima et al., 2021)	Refuse, Rethink, Reduce, Reuse, Repair, Refurbish, Remanufacture, Repurpose, Recycle, Recover
Regulation / Laws	Legal barriers to importing or exporting products to/from other countries.	(de Lima et al., 2021)	Rethink, Reduce, Reuse, Repair, Refurbish, Remanufacture, Repurpose, Recycle
	Waste disposal without consideration about its treatment, exporting it to third countries, causing negative environmental impact.	(European Commission, 2020)	Recycle, Recover
	No uniformity on how the waste must be managed and treated.	(Johansen et al., 2022)	Recycle, Recover
	Different regulations, e.g., EU-defined rules about the products and chemical components that can be used for food packaging, for safety and hygiene reasons.	(PlasticsEurope, 2022); (de Jesus & Mendonça, 2018); (Khan, 2022)	Rethink, Reduce, Reuse, Repair, Refurbish, Remanufacture, Repurpose, Recycle
Costs	Recycled products have become a more valuable raw material to industries that starts to struggle to get them.	(Network for Circular Plastic Packaging, 2020); (de Jesus & Mendonça, 2018)	Rethink, Reduce, Reuse, Repair, Refurbish, Remanufacture, Repurpose, Recycle
Sorting and Collection Processes	Some products are contaminated due to inappropriate separation and sorting of waste by consumers and companies.	(Johansen et al., 2022); (Lowry, 2022); (King & Locock, 2022); (Reike et al., 2018)	Refuse, Rethink, Reduce, Reuse, Repair, Refurbish, Remanufacture, Repurpose, Recycle, Recover

Barrier	Description	References	Rs impacted
Marketing and Perceptions	Lack of knowledge, emotion, and mental perception cause deficient trust in the quality, timing, and availability of customer assistance on products that are not new.	(de Lima et al., 2021); (Awan et al., 2022)	Refuse, Rethink, Reduce, Reuse, Repair, Refurbish, Remanufacture
	Producers aren't aware of the market trends that could increase CSC, such as environmental consciousness, acceptance of "product as a service" and "servitization"	(de Jesus & Mendonça, 2018)	Rethink, Reduce, Reuse, Repair, Refurbish, Remanufacture, Repurpose, Recycle
	Greenwashing uses sustainable language to promote unsustainable activities.	(Robinson, 2004)	Rethink, Recycle
Technologies	Companies and people may face difficulties working with new technologies within the company and with the SC partners.	(de Lima et al., 2021); (Network for Circular Plastic Packaging, 2020)	Rethink, Reuse, Repair, Refurbish, Remanufacture, Repurpose, Recycle, Recover
	Technology can be a barrier when an appropriate solution is not developed to facilitate the process.	(de Jesus & Mendonça, 2018)	Rethink, Reuse, Repair, Refurbish, Remanufacture, Repurpose, Recycle, Recover
Finance	Technologies help in the sorting process however, they aren't affordable to everyone.	(de Jesus & Mendonça, 2018)	Refuse, Rethink, Recycle
	The recycling process can require high energy consumption, pushing up costs.	(Reike et al., 2018)	Refuse, Rethink, Recycle, Recover
	SMEs struggle to get financing to develop and invest in a circular model since the return is not predictable and assured.	(de Jesus & Mendonça, 2018)	Refuse, Rethink, Reduce, Reuse, Repair, Refurbish, Remanufacture, Repurpose, Recycle, Recover
Human Resources and Logistics	The decisions are made by humans, which means their skills, beliefs, and norms are determinants of the process. Complex decisions are often conflicting leading to a longer transition.	(Awan et al., 2022); (de Lima et al., 2021); (de Jesus & Mendonça, 2018).	Refuse, Rethink, Reduce, Reuse, Repair, Refurbish, Remanufacture, Repurpose, Recycle, Recover
	Multiple decision-makers, infrastructures, and lack of coordination in the network are not clear designs to assure the circularity of the products.		

2.4. The Role of Technologies in Circular Supply Chains in the Plastic and Packaging Industry

The boom of new technologies is helping companies to increase the efficiency, productivity, and quality of products (Awan et al., 2022), allowing decision-makers to have accurate and up-to-date information to make their decisions (Simonetto et al., 2022a). Likewise, it is considered that technologies can be a great ally in the shift to more circular business models.

The most relevant technologies that can contribute to CSC in the PPI identified in the literature can be divided into (1) Digital Technologies, such as the Internet of Things (IoT), Big Data, Cloud Computing, Artificial Intelligence (AI), Blockchain, Sensors, Robots, and Cobots; and (2) Other Technologies, such as Recycling technologies and Tracer-Based Sorting.

2.4.1. Digital Technologies

Digital transformation fosters competitiveness and innovation of companies, optimizing processes and leading to Industry 4.0, which refers to the integration of many digital technologies and systems promoting cooperation between departments and firms along the SC, and can highly benefit manufacturing industries for being reliable, and flexible, increase efficiency and profit. However, this creates many doubts about security, trust, potential privacy and security data breaches and traceability along the SC (Feliciano-Cestero et al., 2023; Mohamed & Al-Jaroodi, 2019).

Blockchain can enable a transparent SC since everyone involved has access to the necessary information with a high level of security based on immutable encrypted data almost impossible to manipulate, ensuring trust among the SC (Guruswamy et al., 2022).

A wireless network system of devices with electronic circuits capable to communicate with each other and exchanging data (e.g., sensors, RFID, QR codes, GPS) can be implemented in the products, making IoT one of the technologies mostly used to collect data "from the farm to the fork" for providing reliable information along the SC about the products. This means that a route or a spoiled batch can be easily traced, and it is easier for producers to control their inventory, keep information about agreements and contracts and ensure product/brand authenticity. And, once consumers are becoming more comfortable with connective on their houses, data can be collected to provide a better understanding of consumptions habits and demand changes, as well as how they manage a product at its end-

of-life cycle, helping companies to define effective marketing strategies and trace the environmental impact of their products (de Giovanni, 2022). For example, the Italian brand Barilla implemented sensors and, when scanning a QR code on their packages, the consumer has access to information "from the farm to factory to point of sale" from that batch. This allows Barilla to decrease food waste, since all the path of the product (from production to recycling) will be available on that QR code, improving its production process, and understand its environmental footprint (optimizing delivery routes) (AYZ, 2017; de Giovanni, 2022; Hanson, 2017; Helander, 2020; Simonetto et al., 2022b).

All this large quantity of data is collected and stored in a cloud server system (for example, Microsoft Azure), creating a "supercomputer" (Cloud Computing) capable to process and analyze this Big Data to measure and extract useful information that can help to optimize processes, measure quality parameters, predict trends or can be used to train AI, improving algorithms and making it possible to think independently and predict decisions across the SC in real time, working all as an ecosystem of automation (Guruswamy et al., 2022; Simonetto et al., 2022a).

These innovating technologies are pursuing the human abilities applied in collaborative robots (cobots); ergonomic and responsive devices controlled by a computer to work in direct collaboration with humans. Robots' creativity and accuracy enhance the SC's productivity by reducing risks and human errors and performing tasks considered dangerous to humans (Guruswamy et al., 2022; Simonetto et al., 2022a).

2.4.2. Other Technologies

The difficulty of industries to get good quality recycled material is becoming higher, thus technologies that provide an efficient sorting process are gaining relevance. Recycling is the oldest R strategy used on the PPI, and its technological innovations have been crucial to its success. Mechanical Recycling is the most common process, where the plastic goes through a scanner that recognizes and sorts them by type of polymer and by color, and by density diving in water (Network for Circular Plastic Packaging, 2020), complemented by Chemical Recycling that is thermochemically decomposes plastics into its original molecules giving rise to new products (Dow, 2021; Network for Circular Plastic Packaging, 2020). Biological Recycling can only be done with biodegradable plastics where bacteria and enzymes broke down plastic into raw material (PlasticsEurope, 2022).

Tracer-Based Sorting (TBS) is a technology that combines different types of sorting processes to maximize the number of products collected (Laird, 2022) it uses optical technology of fluorescence X-ray, to recognize a mark included in the plastic during its production, identifying its composition and type of product. (Laird, 2022).

3. Methodology

This study uses a qualitative approach, considering a descriptive and interpretative perspective triangulated with the literature review and a single-case embedded study, cross-border. Information was collected from primary sources (eleven semi-structured interviews with people across several sites and departments and observation on two sites) and secondary sources (documentation on the company's website, videos and articles on social network and press, internal documentation, and a panel discussion on an international fair), aiming for a better understanding of the efforts of the PPI towards a CSC.

A methodology refers to the design of choices and analysis of an investigation, linking the theory with the data collected during the study. The most common types of research techniques are experimentation, interviews and surveys, observation, analysis of documents, and case studies. Qualitative methodologies are distinct due to their flexibility, allowing the refining and revising of the research throughout the process, ending with an analysis of a set of opinions (Bauer & Gaskell, 2000). A case study is a method of investigation that, according to Yin 2009) and (Babbie, 1986), is more suitable for linear investigations of complex social phenomena when the boundaries between the phenomenon and the context are not clear and when there are not many studies about the topic yet, and it is not possible to measure results since the data available is subjective – the data collected is liable to interpretations of each person, their personality and cognitive skills, and the daily events and actions involved during the investigation (Silva & Silva, 2013). Thus, case study research is appropriate, with interviews, to give sense to the perception of the phenomena (Major et al., 2018).

To comply with the purpose of this study about the CSC practices that can be applied to PPI, eleven semi-structured interviews were done with people across several departments and sites to allow a global overview of the strategies of the company, the differences in the strategies adopted according to limitations or resources of each site, and how they are applied along the SC.

3.1. Case Selection

To achieve the objectives of the research, a design for the case study had to be defined. Yin (2009) presents four approaches of case studies that can be considered: a single-case, which can be holistic or embedded design; or a multiple-case (holistic or embedded design).

A single case embedded was considered the most suitable approach for this study, given the opportunity to reach a company that is a big player in the PPI, with sites in 18 countries

all around the world, benefiting from a leadership position in innovation and influence along the industry value chain. By being able to access and analyze specifications, barriers, and strategies of the sites, it gives robustness to the case since it allows us to analyze the uniqueness of each site, splitting the industry into multiple relevant units of analysis and better understand the overview that answer the questions of the research.

The company studied (ABC group) count with more than 50 years of experience in the PPI, is present in 18 countries with 31 sites and more than 6.300 employees. As part of its expansion strategy throughout its lifetime, the company has acquired several companies that improved their R&D capabilities to become a business with a full portfolio of innovative products and able to anticipate market trends and needs. Their sustainability strategy inspires them to design sustainable products and close-the-loop, using more recycled material, becoming more efficient, and playing their part in the carbon emissions reduction strategy while helping customers and consumers to be more conscious about the environment.

3.2. Data Collection

3.2.1. Interviews

Eleven semi-structured interviews were conducted, three in person with an average duration of 1.30 hour, and eight were made online (using Microsoft Teams) with an average duration of 30 minutes. All the interviews were recorded for analysis and transcription of the relevant data. Table 2 describes the interviews.

Table 2 - Date and location of the interviews

Interviewee	Date and Place	Department / Responsibilities
A	Teams, February 16th, 2023	Responsible for the sustainability group strategies
B	Teams, March 3rd, 2023	Analise and evaluate the current and possible suppliers regarding their sustainability strategies and help them to improve and be aligned with the policies of the group.
C	F2F, February 22nd and March 21st, 2023	Procurement for rPET (recycled PET) Europe, based in Portugal site
D	Teams, March 6th, 2023	Business Excellence to lead the project to reduce the waste in landfills in all group
E	Teams, March 3rd, 2023	Reduce energy consumption and implement strategies to use more renewable energies
F	F2F, March 13th, 2023	Business Excellence and Continuous Improvement for the site in Poland
G	F2F, March 14th, 2023	Procurement for logistic/transport solutions in Europe
H	Teams, April 4th, 2023	Innovative products
I	Teams, April 6th, 2023	Marketing and Sales
J	Teams, April 28th, 2023	Head of Logistics Operations and Continuous Improvement

3.2.2. Collection by Observation

Two visits were made to two sites in two different countries (Poland and Portugal) that allowed a good observation of all the processes, from the procurement department to raw materials reception, production, warehouses, sales, accounting, and corporative and strategic departments.

3.2.3. Secondary Sources

A variety of supporting materials were used in this study to complement the interviews and observation, such as: (1) the 'Sustainability Report', made every year by the company, available on their website and where are presented the actions already in place and the goals for the future regarding sustainability and corporate responsibility; (2) social network such as "Youtube" and "Linkedin" with content published by the company; internal videos from 'Sustainability Forums", a lecture with a few people from different departments that give their contribute explaining what they are doing and planning to their department; podcasts where decision-makers are invite and interview about sustainability policies; (3) public data from associations to which the company is part of, such as *The Ellen Macarthur Foundation;* and (4) a panel discussion on an international reference fair for packaging, represented by the sustainability manager and the global innovation manager from ABC group, a technical service engineer at a chemical manufacture, a raw material procurement manager at a raw material producer, a technical manager from an non-profit association that represents the complete PET value chain in Europe and a coordinator of a consortium of the stakeholders from the entire value chain of flexible packaging that promotes CE.

4. Results

The analysis of the eleven interviews made, as well as the internal data and visits to the sites, allowed us to understand more clearly the barriers towards a CE in the industry and the strategies in place to overcome them.

4.1.1. Rs Adoption

Positioning itself at the beginning of the distribution chain, ABC company has limited influence over consumer behavior. ABC answers to the needs of the market and invests in an innovation strategy and design that allow it to refuse accessories in its products as well as increase the recyclability of the products. For example, the new design of protein trays, due to their new characteristics, does not need pads to absorb the protein juices. The traditional pads, besides not being recyclable, are often glued to the trays, making it hard to remove them and turning the tray harder or even impossible to recycle. ABC has also invested in a shrink sleeve label technology that molds to the design of the package and allows printing any information and design the producer wants, avoiding the need for paper labels that would be glued on and make the package impossible to recycle (Interviewee C).

To reach success, ABC has rethought its strategies (rethink strategy), since the evaluation of the current processes, to identify the weakness and what can be changed, to the definition of the projects about what to change and their impact. ABC has a Sustainability Committee represented by all stakeholders to oversee the implementation of all sustainability initiatives and strategies, which design principles that cover sustainable outcomes, creation, and research to innovate the products of tomorrow (Sustainability Forum of ABC group). This means that that company works to ensure that all their products are designed to be recyclable, to avoid non-recyclable materials or to include materials that are easier to recycle, as well as to reduce the amount of plastic.

In addition to the strategies applied in the production process, other sustainability topics were rethought, such as energy consumption to cut carbon emissions and reduce waste in landfills. The company has adopted strategies that allowed that 28% of the energy consumed in production comes from renewable energy sources and defined the goal of reaching 50% in 2025 and 100% in 2030. To reduce carbon emissions, the factories use a system of recovery heat from the extruders and compressors and reuse it to heat the ambient (Interviewee E). In all factories, it was defined a policy of zero waste to landfills (without energy recovery) that required a strategy to reduce waste from the production to the canteen

and even the products used for cleaning. This policy is already in place around the world since 2022 (except for the sites where the legislation requires the use of landfills) (Interviewee D).

The legislation establishes that the basis for a CE is the possibility to reuse materials. Besides the strategy to incorporate damaged materials during production at the beginning of the processes again as raw material, one of the most important initiatives of ABC group is the strategy to use more products as raw materials through recycling, that usually went to landfills or incineration. Due to the high requirement of the legislation of food compliance, the only recycled materials that can be used on food packaging are materials that already served as food packaging. For a long period, the only product that was recycled for food packaging was water bottles, which components and quality are well known. These packages are easy to work with, and all the recyclers have the technology available to sort and recycle them. However, in the last years, the price of the PCR plastic (post-consumer recycled plastic) has increased drastically, due to the rising demand (prompted by legislation and social pressure from consumers) and limited quantity (constrained by the lack of technological capacity for recycling and sorting of waste management companies). To increase the amount of raw material available in the market, ABC group started to encourage the reuse of protein trays in the production process. By containing a lower viscosity index, trays were commonly considered a lower quality product that would impact the quality of the final packaging if used as a raw material. After conducting several tests with recyclers, it was possible to prove that, with the correct sorting and recycling process, it is possible to do it. Despite the success of the finding, ABC refused to sign exclusive contracts with the recyclers to stimulate the market and increase circularity (Interviewee C).

During the study, a strategy was observed that can be defined as repurpose, about the system recovery heat from extruders and compressors that are used to heat the ambient (Sustainability Report). However, for production, ABC group does not accept the concept of repurpose as per definition, as it could create misleading claims about something being more sustainable or more circular than it is, since it looks into the availability of well-established recycling streams but without the presence of any specific product design guidelines or assurance the product will end up in recycling (Sustainability Forum).

The ABC group can only influence the recycling strategies since the main solutions are done by recycling and waste manager's companies. By using more recycled material – at least 30% of PCR plastic until 2025); and by making their products even more recyclable – all

products would be 100% recyclable until 2025; ABC increases the demand for recycled products and promotes its circularity (Interviewee C). On the other hand, ABC is creating new solutions for their clients, like recyclable labels and printing information directly on the packages, to turn the products more sustainable and recyclable. Over the last few years, ABC has been working in partnerships with waste managers that can guarantee the company's waste will not be sent to landfills, instead, must be assured all waste will be recycled and incorporated back into the value chain or at least incinerated for energy production. To reinforce its position of sustainability, ABC group already ended some contracts with companies that could not offer this guarantee and, with others that showed willingness to fulfill these requirements, an action plan was created and monitored to allow the development of capacities to recycle more materials and with more quality (Interviewee I).

The recovery process is handled by the recyclers in the waste management process, while the other actors in the supply chain are responsible for implementing rules and requirements that may influence their decisions. ABC has a strategy to not send waste to landfills without energy recovery, which means that, in the part of the process where ABC has the power of decision (choosing the company to which send their waste), they choose companies that share the same values and can guarantee this solution (Interviewee D).

It is important to mention that repair, refurbish and remanufacture strategies are not adopted by the company as they are considered not applicable to the PPI industry. Table 3 presents the R strategies adopted by ABC.

Table 3 - R Strategies adopted by the company

R's	Examples of strategies in place
Refuse	- Eliminate the need for pads on the protein trays
Rethink	- Sustainability Committee to oversee the implementation of strategies. - Design principles to embrace sustainable outcomes creating and researching for innovating tomorrow's products. - Design to avoid the use of non-recyclable materials and to reduce the amount of plastic. - Project to ensure that 100% of the energy used is generated from renewable sources. - Developing strategies to recycle more materials, increasing the raw materials available in the market. - Alternative complementary recyclable products, as labels.
Reduce	- Use less energy to cut carbon emissions. - Stop sending waste to landfills without energy recovery. - New product design to weigh less and use less amount of plastic. - System that uses heat production to heat the ambient.
Reuse	- Work with stakeholders to invest in technologies and infrastructures that increase the capacity to recycle new and more products. - Re-incorporation as raw materials of materials damaged during the production process.
Repair	- NA
Refurbish	- NA
Remanufacture	- NA
Repurpose	- System that uses heat production to heat the ambient. - Repurpose concepts, without any product design guidelines or assurance, can create misleading claims about something being "more sustainable" or "more circular" than it actually is.
Recycle	- Use (at least) 30% more recycled material and 100% recyclable until 2025. - Partnerships to improve recycling performance and capacity to raise the amount of recycled material available in the market.
Recover	- Only work with contractors that can assure not send the waste to landfills. - Decrease the percentage of materials wasted that can't be recycled. - Send to incineration with energy recovery the complex materials that are not possible to recycle.

4.1.2. Barriers to the Adoption

The market still faces many barriers to the implementation of CSC strategies. There are too many uncertainties and reluctance to change. People are always resistant to the unknown which causes lack of trust in what is new: new products, new processes, new technologies, etc. To face this lack of trust in new products, ABC group has been working in some countries with a sense of "patriotism", taking benefit of the sustainability concern of the consumer, using national products to be recycled and used in the production of their products, increasing their acceptance (Interviewee I). The market also has some expectations about the products, and there is an urge to make the market aware that some requirements do not change the functionality of the product and should be rethought to progress. For

example, when consumers buy recycled paper there is no expectation to be white; however, when it comes to plastic – specially food packaging, the market expects clear plastic. An aspect that does not interfere with the functionality of the product but, at this moment, turn the recycling process more difficult and expensive (Packaging Fair, 2023).

The requirements of the food sector are particularly stringent, and the Regulations and Laws have ambiguous concepts and are continuously changing, becoming more difficult to comply with the legal requirements (Packaging Fair, 2023). According to Interviewee I, there is no balance between social, financial, and economic factors in the legislation. By having only into consideration, the cheaper price and higher availability, some raw materials are imported fulfilling the legal requirements but not contemplating the environmental footprint of transportation or the human and work conditions of the market (Interviewees C and I). People and companies struggle to decide what to do or where to invest when is not clear what sustainability really means according to the legislation. For instance, it is not clear how many times a product must be recycled to be considered circular, and whether downscale recycling will be accepted or only at scale, there is no guarantee that a product or technology that is accepted today will be allowed in a nearly future (Interviewee H). The European Committee of Normalization and CEFLEX (Circular Economy for Flexible Packaging) are working to standardize the concepts in the legislation, which will hopefully reduce uncertainties and make the legislation clearer. At the same time, ABC group is designing their products to have the same functionality but without hindering recyclability, complying with the current legislation, and increasing circularity at scale (Packaging Fair, 2023).

The company is also investing in Agreements Along the Supply Chain to exert a strong influence to change, even if is established that people and companies will not reach any agreement until the benefits are visible. However, ABC believes that by working together, change happens and can influence others. There is a shift in the last few years, but the SC is still not circular because the companies are not reporting their circular actions or those that are doing, they are doing it without any standardization and measures. By putting in writing what the companies are doing, make them aware of their performance (Packaging Fair, 2023).

As mentioned by Interviewee C, there is a lot of noise around plastic pollution because it is the most visible material, making it easier for people and media to point the finger at plastic as being the most environmentally damaging material. However, it is common to see people discarding their different types of waste through the car window or directly on the ground while walking. In the end, the paper is dissolved by water – and there is no visual pollution

even if the consumer is not aware of the possibility of contamination of the waters by the chemicals on the paper; glass and metal usually sink due to their weight – not becoming visible, while plastic floats and this contamination is easily saw. Thus, plastic is the most visual material and for that, creates more noise in social networks while media that do not speak so much about the other materials by not being aware of the pollution they cause (Interviewee C).

The Internet allows anyone to write and share pictures all around the world and this sometimes-inaccurate information increases the feeling of distrust in the consumers. In this sense, consumers tend not to believe in any message that a company try to send as there will always be some other report or image saying the opposite and it is very hard to understand who is telling the truth. The authorities should develop EPR schemes (programs imposed by governments on producers regarding the management of the packaging life cycle), instruct and make people reflect on the advantages of plastic (as well as other materials), and help them to realize that without plastic it is almost impossible to maintain the standards of living. For instance, China already started a program to educate people about how to take care of their waste (Lee et al., 2020). However, in Europe, despite being the world's most sustainability-conscious region, it is still very complex to understand how to treat and handle the waste (Packaging Fair, 2023). ABC group is working with a social media specialist to learn how to adapt the message to the market according to cultural differences, perceptions, and doubts. However, there is a strong belief that behaviors will only change through new legislation and taxes that will condition or encourage actions (Interviewee I). Nevertheless, for the coordinator of the consortium present on the international fair:

"I think this industry (PPI) has to stop throwing the problem over the fence and blaming the consumers. We know we can get everything back; everything is collected one way or another, and very little gets littered into the environment, it just costs a lot more to collect, sort, and recycled it if is not coming back by a separately collected steam. If we want to do it, we just have to pay for it and we all know how it gets paid. It is added to the price of the pack, so the consumer is paying for that at the end of the day anyway (…) so we just need to put our money where our mouth is".

As tested in Germany, 90% of the plastic packaging is collected, and it gets a sorting yield of around 80% (there's always contamination in some products) and 75% is recycled (considering mechanical recycling operations), with 10 to 20% moisture there, gives 54% of

recycled material, and the target for Plastic Packaging Recycling in 2030 is 55% in Europe, which means going from linear to circular in one step (Packaging Fair, 2023).

For the PPI, the Costs are a considerable issue. In production the higher percentage of the costs come from energy consumption, a resource that has been increasing in price and most of its source is not sustainable – four sites of ABC group have already installed solar panels that allow covering 7% of their consumption and there is an aspiration for 100% renewable energy by 2030 through investments in energy corporate deals and certificates of carbon offset. It is impossible to change all at the same time or use the same strategy, so the company will choose according to the best financial cases. This means an analysis of the amount of land available in the factories where it is possible to install sollar panels, the cost of energy in each country, the inflation and conditions to long-term leasing contracts for the panels, the government incentives to invest in renewable energies and there is also a task force team that looks for projects to save energy and efficiency of machines. The European Union has more flexible conditions for investment, which makes it easier to invest in one country and share the benefit with others (Interviewee E). Another part of the considerable costs is in the raw material price, which is higher and higher, and in several countries, the recycled material is sold at auction and is sensitive to speculation (Interviewee C).

The SC is willing to invest in new technologies that work as a facilitator of the circularity to increase the amount of PCR plastic available and lower costs. The costs are usually very high but if it represents a good solution and complies with the legislation, at the end this cost will be pushed to the consumer. However, to invest in renewable energies there are still not many suitable technological solutions on the market (Interviewee E), and there's some reluctance to invest in Sorting and Collection technologies without knowing which one is the best solution and decreasing the risk of losing money on the investment. Some technologies are complex and required to be handled by specialists, and it may be difficult to find available and qualified Human Resources.

However, despite the barriers observed, the PPI is a very open market where most of the information is shared and there is not much afraid with Privacy and Protection of data risk - there are not too many actors in place, by sharing information help to develop the market. Once ABC group started to investigate the possibility of recycling protein food packaging, they refuse to sign any non-disclosed or exclusive agreement, instead, promoted and advertised believing that is the way to show the market the relevance of the finding and increase the circularity (Interviewee C).

Table 4 - Barriers to the Adoption faced by the company

Barriers	Barriers Identify	Strategies in place
Uncertainties	- Resistance to change. - Lack of trust in new products and processes. - Legislation is unclear and confusing.	- Marketing appealing to patriotism to increase product acceptance. - Promotion of the products through fiscal benefits. - Consortia strengths to influence changes, approvals, or clarification in the legislation. - The European Committee of Normalization is working to standardize the legislation and its concepts.
Agreements along the Supply Chain	- The stakeholders and different actors along the supply chain will not reach an agreement until its visible its value.	- Collaborative strategies to act responsibly and prevent pollution. - Solid partnerships, supplier engagement, and cooperation to recover as much plastic as possible to reuse in food packaging. - Work with recyclers to develop new technologies. - Supplier Code of Conduct: design to ensure better performance in key areas and inspire the partners to reach beyond compliance with regulations. - An external rating assessment to evaluate the sustainability performance improvement. - The legislation acts as a reinforcement of the agreements.
Privacy and Protection	- NA	- NA
Regulation / Laws	- Requirements of the food sector. - Taxes for the use of single-use / virgin plastic. - Concepts and definitions of sustainability are constantly changing, making the future unpredictable.	- Design products complying with regulations. - Initiatives to increase the amount of raw material that meets regulatory criteria. - Agreements along the SC to comply with legislation and prevent its changes due to bad treatment of waste.
Costs	- Recycled raw materials are becoming scarce and its cost higher. - The higher percentage of production costs comes from energy consumption, a resource that is expensive and not sustainable. - Investors' Expectations. - Inflation.	- Partnerships with stakeholders to increase the rate and cost-effectiveness. - Initiatives to increase the amount of raw material and to promote circularity and recyclability at scale. - Invest in EU countries with flexible conditions that allows to share the benefit in all countries.
Resources	- Scarcity of recycled raw materials. - Poor infrastructure for collecting sorting and recycling.	- Work with recyclers to develop new technologies. - Marketing appealing to patriotism to increase circularity. - Solid partnerships, supplier engagement, and cooperation to recover as much plastic as possible to reuse in food packaging. - Encourage consumers to recycle more.

Barriers	Barriers Identify	Strategies in place
Marketing and Perceptions	- Complexity of customer needs and geographical distribution. - Sustainability awareness from the consumer. - Noise on mass media about plastic contamination. - Wrong message – society points fingers instead of changing behavior.	- Encourage consumers to recycle more, working with others to improve infrastructures and incentives. - Recycling initiative to help to meet customer expectations. - Redesign products to make them clearer and more convenient for the end consumer. - Marketing as a promoter of the Circular Economy. - Taxes and legislation as a behavior's changer. - Adapt the language of the message according to whom is directed.
Technologies	- Needs to be handled by specialists. - Difference in waste management technologies between countries. - There are still no good technology solutions on the market for renewable energies. - Innovation requires a high investment with no certainty if it's the best solution.	- Design products to deliver superior performance. - Invest in the market and align with suppliers to develop more efficient technologies to create the need in the market. - Work with stakeholders to develop new technologies.
Human Resources and Logistics	- There isn't enough land and space on the plants to install too many solar panels.	- Investment in energy corporate deals and certificates of carbon offsets.
Sorting and Collection	- Waste is not properly separated by the consumer. - Waste management companies do not have the technology for effective product sorting. - The improper separation, collection, or sorting leads to contamination. - Different technologies between countries.	- Partnerships with municipal waste services to develop an effective sorting system. - Waste stream analysis, clear action planning, standardized waste, separation processes, a good level of understanding among the team, and making the switch to new waste contractors. - Contractors are selected entirely based on their ability to offer zero-landfill solutions.

4.1.3. Participation of Supply Chain Partners

There is a belief that once it is reached a global mindset, the value chain can work together to prevent scarcity of raw materials, giving a good message to policymakers and trying to avoid unnecessary changes in the legislation due to the bad treatment of waste. The key is communication and having the same mindset along the SC, ABC believes that change can happen and can influence others (Packaging Fair, 2023). As an example, ABC Group is part of a consortium that works together with the authorities to request approval about functional methods of recycling and new technologies, since the SC is only willing to invest once it is clear what will be approved or forbidden according to the legislation (Interviewee H). These agreements exert a strong influence to change, even if it is established that people and companies will not reach any agreement until the benefits are visible. For example, by working with the recyclers to improve the technology and capacity to recycle the food protein packs, the market demand for this product increased which leads the waste management companies to improve their capacity to collect and sort this material (Interviewee C); by working with the manufactures, customers, governments, and consumers some collaborative strategies are defined to act all responsible and prevent pollution – the ABC group created a Supplier Code of Conduct to ensure a better performance of the SC in key areas as environmental impact, conflict minerals and governance, and to inspire it to reach beyond compliance with regulation, with the highest standards – these practices are rated by an external assessment provider that evaluate the sustainability performance improvement of the companies (Interviewee B).

One goal of the ABC group is to be able to influence and work with the SC regarding CE. Since they are positioned almost at the beginning of the SC, where their direct clients are food processors/packers, it is difficult to influence and communicate with the final consumer whose idea of the plastics industry is not very positive, due to Misperceptions and inaccurate Marketing messages. Customers' needs are very complex, and they are demanding more recycled packaging due to their main concern about pollution and contamination. This concern has focused mainly on plastic products because of the noise in mass media about plastic contamination that surrounds the consumer with unclear information, increasing their trust issues in the products and about which information is or is not true (Interviewee I). Marketing works as a promoter of the CE since the use of 'recycled products' and 'recycled materials' is a demand of the market and a trend for the brands. However, society is pointing fingers instead of changing behavior. All materials have their environmental footprint,

whether glass, plastic, metal, or paper, and the focus on the message that 'plastic is not good', is leading companies to adopt other solutions that are not the best choice from a greenhouse gas emission perspective (Packaging Fair, 2023).

As part of this study, and to better understand the perceptions and barriers on the SC towards a CE, a company delivering transport management solutions (Company T) gave its contribution and vision about this industry, about the strategies they have in place as the barriers they struggle to overcome with the other actors of the SC to reach an agreement and be all more sustainable. Company T has more than 20 years of experience and is present around Europe and it was represented by Interviewee J, Head of Logistics

4.1.4. Technologies

Technologies have been working as a driver of the CE in this industry by enabling the development of better-quality products more efficiently. The latest technologies have also changed the way information is processed, now allowing the processing of larger amounts of information, ensuring its reliability to transmit confidence, and speeding up the processes.

Robots are being used to help with the transportation of heavy loads in the factories, increasing the well-being of the workers but also allowing them to focus on other tasks, automatizing process since they can move the products from one point to another according to what is set up in their systems (Interviewee C and F, visit to sites in Poland and Portugal).

Traceability technologies are strengthening trust in SC with initiatives such as *RecyClass* – a non-profit cross-industry – that help and certify companies regarding their recyclability processes through scientific findings, reliability, transparency, and traceability of the plastic. To ensure traceability, the SC is using software such as 'SAP traceability' (a smart system that allows quickly identify and tracing products of a batch manufactured, distributed, or sold), 'Tromba' (a system solution developed to work with cities and waste management companies for a better sorting and cleaning solution), and 'Holy Grail' (a digital and invisible watermark that carries information that can show to authorities that food safety regulations are fulfilled and can be detected by scanners on the sorting lines, improving the accuracy of sorting of packaging waste and increasing the amount of material recovered to recycling).

In fact, the 'Holy Grail' system is pointed out as:

"*(Holy Grail) project can be a real game changer because it would allow an efficient sorting.*"

"*a great solution because it allows traceability that would demonstrate that we (the packaging producers) are using less than 5% of the material coming from non-food applications"* (a legal requirement for food packaging)

Packaging Fair, 2023

One of the key points to circularity is the amount of PCR plastic and for that, the industry is investing in technologies that assure the quality of the product during its production, such as an Optical Control System (OCS) that analyze the plastic after is melted and begins to be laminated through an optical scanner that identifies possible defects in the product, according to the manual parameterizations defined; as modern sorting equipment on the sorting lines, that use Near Infra-Red (NIR) to identify polymer types and better sorting the waste to be recycled increasing its quality and quantity available (On site, Portugal), and 'SuperCleaning' technology, a reactor that uses vacuum to clean the plastic on a level within the legal parameters and that helps to maximize the use of PCR plastic - a consortium of multiple supply chain stakeholders have presented this technology to regulators for approval as a technological solution to recycle food plastics.

New data processing technologies have been adopted throughout the SC to acquire more accurate and reliable data and avoid unnecessary waste. Recurring to Big Data, Cloud Computing, and Artificial Intelligence, the SC can process a big amount of data in real-time that helps make decisions. For example, for Interviewee J, these technologies are used to collect data and provide the best logistical options for transportation. With a business SaaS (software as a service), this stakeholder act as a delivering transport management solution able to work with producers and customers to meet their transportation needs in an easy, affordable, and sustainable way, collecting real data that is processed in its system to determine the most optimal routes according to time, cost and ecological footprint.

5. Conclusions

Considering that plastic is one of the most used materials worldwide, but its production and consumption are becoming a concern due to its environmental impact, this study aimed to investigate how do circular supply chain practices can be applied in the plastic and packaging industry and contribute to increase environmental sustainability.

A study on a big player in the sector was performed, considering a descriptive and interpretative perspective triangulated with the literature review and a single-case embedded study, cross-border, getting the information from eleven semi-structured interviews, visits at two sites, documentation on the company's website, videos and articles on social network and press, internal documentation and a panel discussion on an international fair, to better understand the efforts and motivation along the SC in this industry.

The findings in this study reveal that even if there are differences between the countries, they are not substantial enough to make a comparison, as the company works to standardize its processes and strategies on all sites.

It needs to have a balance on the path between innovation and scales up, a step-by-step approach that requires time and investment, and realize that economic factors are important. The industry needs to put aside its differences and starts thinking about sustainability and explain to the world how the PPI can help with climate change objectives, then it can invest in a way to be profitable, instead of just saying that is not possible to do it.

There are several strategies identified in the literature towards CSC. It is possible to identify common strategies suggested by the authors that are already in place or being recognized by the industry. However, there were also differences in the best strategies identified. Throughout the literature review it is notable that there is not yet a clear understanding of which strategies are most suitable for an industry or which ones should be prioritized mostly because this transition to CSC is sluggish as there are several barriers and uncertainties regarding each one of them. These uncertainties focus essentially on whether the amount of raw material that is collected and recycled, and suitable for production, will be available in sufficient amounts to cover the market needs; if the implementation of CSC strategies allows to preserve of the quality of the raw materials and, therefore, of the products; and what is the room for improvements. This case study analysis presents a set of successful strategies that can be replicated both within and outside the PPI sector as well as the difficulties faced by the company. Investments in technology and innovation have promoted this transition promising to clarify the process to close the loop, making it fast,

and efficient, raising the quality of processes and products, and thereby decreasing uncertainty and surpassing some barriers.

5.1. Implications for Theory

This study contributes to the literature by focusing on the PPI combining an analysis of the 10 R strategies specific to the sector, as well as the barriers to the implementation of CE, and providing a baseline for further theoretical studies and analysis of companies in the industry.

The study reveals that, at the moment, the PPI considers that the strategies Repair, Refurbish, and Remanufacture are not applicable since when a product is damaged, comes back to the loop as raw material. Additionally, the results demonstrated that there are still few actions in PPI to Repurpose due to the possibility of misleading claims about something being "more sustainable" or "more circular" than it actually is. Recover is a strategy that is being developed through the industry's efforts to avoid landfill, and to engage with recyclers who ensure that, at least, the waste is used to generate energy. The clearest efforts can be observed in Recycle - with the investment in new technologies to be possible to recycle as much products as possible; and in Rethink, which is intrinsically linked to Refuse and Reduce. Reuse, especially when it refers to food packaging can be difficult to apply due to the legal requirements, however, can be already observed in some actions promoted by brand owners, especially in retail (Unilever, for example (Unilever, 2023)).

The new technologies and innovations, specifically blockchain, enhance transparency and trust, promoting communication in the SC. Recycling technologies will improve and complement each other as they have different purposes, different costs, and different footprints (Packaging Fair, 2023).

5.2. Contribution to Practice

Considering the attention that sustainability has attracted from researchers, policymakers, managers, and all sorts of stakeholders, the findings of this paper could be relevant for the management of plastic and/or packaging companies and any other actors in the value chain by presenting strategies towards a CE. This study presents a set of successful strategies that can be replicated both within and outside the PPI sector. Furthermore, the barriers identified

in this study can support other companies during the difficult task of developing circular strategies.

By working together and reaching agreement along the supply chain, the industry can influence the market, consumers, and policymakers. Consortiums can gain strength by showing innovations and strategies that can promote sustainability and reveals the importance of plastic to the consumer when properly treated and handled. The companies can better understand the needs of each other and complement them to work in a more circular process – for example, the investment in the process to recycle food trays, lead to an investment of waste management companies in technologies able to identify the trays and separate the ones needed by ABC (monolayer trays), which in return found a company capable of recycle the multi-layer trays, giving them a purpose (for other companies and markets) instead of ending up in landfills. This is seen as an essence of agreements and projects along the SC that can be replicated for other projects and sectors.

For being a market that is being pressured by consumers and legislation, PPI is an industry investing in the innovation of new products and new technologies that will serve the market's needs and fulfilling the legal requirements. New design products can reduce the need for complementary materials, leading to a more efficient recycling and easier understanding of the process for the consumer.

Technology and innovation are an enabler of circularity by increasing transparency and trust. The use of big data optimizes the flow of information while artificial intelligence and IoT are fundamental to collecting information and recording on the blockchain, ensuring traceability, and resulting in increased trust among stakeholders when buying and using recycled products. Recycling technologies will progress however, despite the 'Holy Grail' project being pointed as a game changer to the industry, this technology can be in danger if not supported by brand owners and retailers to pull this technology in the market at scale and promote the interaction in the SC (Packaging Fair, 2023).

5.3. Limitations

A case study is adequate for this type of research when there is not much data available yet and the interpretation may vary from person to person based on a wide range of considerations, such as personality and cognitive skills, as well as daily events that occurred during the investigation. However, this study is not free of limitations and their results cannot be generalized, which can increase interest in the topic and inspire future research. There is

no clear understanding on what circularity means or how can be measured. The R strategies can be a useful standard to evaluate the impact of circularity, however, the uncertainties in the interpretation of the legislation can cause misleading claims about something being more circular than in fact, it is, leading to misleading 'greenwash' claims. Therefore, the major limitation of the present study is to reach empirical and quantitative results of the phenomena studied.

5.4. Future Works

Future studies can consider the triangulation of multiple sources, as government and small companies that may have different barriers. Additionally, future studies can propose indicators for a more empirical and quantitative assessment of circularity on the PPI and could be replicated in other industries.

Strategies such as reuse could be more developed by the industry and in future works to better understand how the producers and brand owners can promote this strategy and pull the market. Finally, repair, refurbish, and remanufacture could be targeted to invest by chemical companies, to innovate and create sustainable solutions, which could allow the implementation of these strategies.

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